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Intermanual Transfer of a Novel Writing Task in Young Adults without Disability: a Kinematic Perspective

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INTERMANUAL TRANSFER OF A NOVEL WRITING TASK IN YOUNG ADULTS WITHOUT DISABILITY: A KINEMATIC PERSPECTIVE

by

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An Abstract

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The complexities of motor learning are an important and integral part of the practice of occupational therapy. Intermanual transfer of motor learning is a specific area of interest that has significant relevance to the specificity of clinical motor training activities utilized in therapy. The term refers to the transfer of upper extremity motor skills previously learned by one cerebral hemisphere of the brain to the other cerebral hemisphere. Understanding the complexities of motor learning is important to occupational therapists as they develop strategies to be used with applicable clients with motor disabilities. Integral to this premise is the notion that clients who have lost function in one limb may relearn motor behaviors by accessing previously learned skills from the relatively unaffected contra-lateral cerebral hemisphere. Recent research indicates an inter-hemispheric dependence for the development of upper extremity motor skills and intermanual transfer.

This study investigates intermanual transfer in a group of ten right-handed subjects with no known motor disabilities. Each subject learned to perform a novel motor task that included practice, original learning, and transfer learning involving distal muscle groups. The task required the writing of an alphabet letter of a foreign language. During the practice sessions, the subjects traced the letter six times either with their right or left hand. In the original learning sessions, the subjects used the same hand as in the practice sessions to reproduce the skill without the letter in view. In the transfer learning sessions, the subjects reproduced the skill with the contralateral hand. Once that protocol had been completed, subjects switched hands to begin the sessions again using the opposite hand. Movements of the pen were recorded using the search coil system to assess kinematic performance. Simultaneous electromyography (EMG) recordings of the first dorsal interosseus muscle were performed to measure distal muscle activity.

EMG and kinematic data were analyzed to compare motor learning between the dominant hand transfer of learning to the non-dominant hand and the non-dominant hand transfer of learning to the dominant hand. Analysis indicates an almost full transfer of the learned motor task between hands, ranging from 80-100% for left to right and right to left conditions. Findings strongly suggest that the contra-lateral motor learning resulting from inter-manual transfer functions might be useful for promoting unilateral or bilateral upper extremity motor rehabilitation.

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CERTIFICATE OF APPROVAL

This is to certify that the Thesis of

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Chapter 1 Introduction

Background

The countless skilled movements that we make in our everyday lives are essentially learned through repeated practice. A few examples of these everyday motor skills include writing, driving, and using a fork and knife. A motor skill is usually learned through specific body parts and under specific settings and rules. As the proficiency of the skill develops, the learner begins to generalize the skill for performance in different settings and utilizing different limbs. This is called transfer of skill learning. One learns to write on paper utilizing finger and wrist movements. However, once learned, a person can readily transfer this skill to more proximal body parts when he or she writes on a blackboard using shoulder and trunk movements. The process through which we acquire, retain, and transfer these skills is called motor learning (Schmidt, 1988).

Recently, a number of reports have been appearing in the literature drawing parallels between motor learning principles and occupational or physical therapy practice (Burgess, 1989; Carr & Shepherd, 1989; Crutchfield & Barnes, 1993; Ferguson & Trombly, 1997; Glickstein & Hudak, 1999; Hanlon, 1996; Jarus, 1994; Poole, 1991; Sabari, 1991). However, these studies have mainly concentrated on the practice learning occurring during skill acquisition and the factors that affect the acquisition process. There are two other important aspects of motor learning which are minimally addressed in these reports and these are the importance of retention and transfer of motor learning in therapeutic practice. During motor learning or retraining, it is equally important not only that the client be able to retain the skill acquired through repeated practice, but also be able to transfer that skill to a different context or setting. As for example, when a client with unilateral stroke is relearning to put on a shirt in the rehabilitation clinic, it is expected that the client would be able to put on a different shirt in different environmental contexts, such as at home. This is called contextual transfer of motor learning (Schmidt, 1991).

Motor learning research suggests that transfer of motor learning can also occur from the portion of the limb used during practice to the contralateral limb. In the case of upper extremity skill acquisition, the transfer of skill from one upper limb to the contralateral upper limb is called intermanual transfer. Take for example the unilateral skill of handwriting. A person acquires this skill through his/her dominant hand. However, if the person tries to reproduce a piece of writing with the non-dominant hand, the writing will still be identifiable as unique to that person in spite of obvious degradation in quality. Therefore, despite a varied degree of deterioration, there will be some invariant characteristics associated with the performance that is identifiable with the skill. The invariant characteristics of motor skill transfer, consisting of spatial and temporal properties of movement, gave rise to the theory of generalized motor program (Schmidt, 1988). An essential component of this theory is that the learning of a skill is goal specific rather than limb or context specific (Kaluzny, Palmeri, & Wiesendanger, 1994) and therefore, can be transferred to a different context or limb.

The principle cause of intermanual transfer has been attributed to the efficiency of the information exchange between the two cerebral hemispheres via commissural fibers in the corpus callosum (Hoptman & Davidson, 1994; Thut, et al., 1997a). A few studies that have attempted to understand the nature of intermanual transfer have found that the direction of such transfer exchange is asymmetric rather than symmetric (Edwards & Elliot, 1989; Parlow & Kinsbourne, 1990; Stoddard & Vaid, 1996). In other words, this means the transfer advantage, or benefit of skill exchanged from one side to another, is not complete, rather, it degrades during the transfer. However, when the results were examined with respect to whether the benefit was greater for dominant hand transfer than the non-dominant hand, studies obtained inconclusive results. For example, using a variety of sensorimotor and visuomotor tasks that have different spatial and temporal characteristics, some researchers found a left-hand advantage over the right hand in relearning the skill (Halsband 1992; Laszlo, et al., 1970; Parlow and Kinsbourne, 1989) while others have found a right-hand advantage over the left hand in relearning a skill in right-handers (Hicks, 1974; Taylor and Heilman, 1980). Thus, it might appear that transfer advantage is not guided by handedness but rather by task characteristics.

A model has been proposed to explain the transfer advantage associated with motor learning. This model is known as the cross activation model (Parlow & Kinsbourne, 1989). According to this model, it is assumed that whenever a novel skill is learned a dual motor memory (engram) is formed in both the cerebral hemispheres irrespective of the hand used to acquire the skill. Thus, the directional advantage of transfer may depend on the spatio-temporal characteristics of the motor task since there is a known difference between hemispheric function in processing of such information. For example, the right hemisphere is superior to the left hemisphere in processing spatial (amplitude or accuracy) properties and the left hemisphere is superior to the right hemisphere in processing motoric (temporal or sequential) properties of a task. Therefore, it can be reasonably assumed that the left hand will have a benefit of transfer in the re-acquisition of the spatial properties of a task over the right hand because of the direct control the right hemisphere has over the left hand. Conversely, the right hand will have a benefit of transfer in the re-acquisition of the motoric properties of a task over the left hand because of the direct control of the left hemisphere over the right hand.

One way to measure a motor performance is to analyze the kinematic parameters of movement made during a motor act. A number of studies are reported in the occupational therapy literature based on kinematic analyses of movement (Cope and Trombly, 1998; Hall and Nelson, 1998; Hall and Nelson, 2000; Mathiowetz and Wade, 1995; Wu, et al., 1994). In the kinematic analysis of movement, the movement parameters over time are recorded by attaching markers or sensors to the moving body parts. Two important parameters to consider are the amplitude of the movement and the duration of the movement apart from the velocity profile (Brown & Cooke, 1986). Movement amplitude represents the extent of excursion of a limb through space and can be expressed in degrees much like the measurement of range of motion. Duration of a movement refers to the time from start to finish taken by the movement and is expressed as milliseconds or seconds. Movement amplitude made under the emphasis of accuracy reflects the spatial properties of the movement while the duration of a movement reflects the temporal properties of a movement (Thut, et al., 1996).

Almost all of the studies addressing the issues of intermanual transfer of motor learning use non purposeful tasks that bear no meaning to the participants. Therefore, in order to carry-over the implication of intermanual transfer of motor learning in occupational therapy practice, it is imperative that a study should be carried out employing a meaningful occupational task. The present study proposes to study the intermanual transfer of motor learning in a novel writing task employing kinematic parameters.

Problem Statement

The knowledge of motor learning is an important and integral part of the practice of occupational therapy. Intermanual transfer of motor learning is a specific area of interest that has significant relevance to the specificity of clinical motor training activities utilized in therapy. The term refers to transfer of upper extremity motor skills previously learned by one cerebral hemisphere of the brain to the other cerebral hemisphere. Knowledge about the neurological transfer capabilities for learned motor movements might assist clinical practitioners to develop more effective therapeutic strategies that can be used with motor disabled patients. Integral to this premise is the notion that clients can learn or relearn to perform motor behaviors by accessing previously learned skills from the relatively unaffected contra-lateral cerebral hemisphere. Clearly, research support for intermanual transfer would indicate an inter-hemispheric dependence for developing upper extremity motor skills.

Rationale of the Study

The concept of intermanual transfer has important implications in therapeutic practice as the knowledge of transfer can be utilized in regaining or retraining some of the skills disrupted following unilateral damage to the brain, as in stroke patients, or in unilateral amputation (Jarus, 1994) affecting the dominant hand. Such knowledge may allow occupational therapists to plan treatment to allow recipients to efficiently regain control over injured muscles or relearn skills through the use of functional activities by taking advantage of the already learned skills of the uninjured or relatively unaffected side of the body.

Definition of Terms

Motor learning: The development of general strategies used to solve movement problems in a variety of contexts. Motor learning occurs in three phases: skill acquisition, retention, and transfer (Schmidt, 1988).

Intermanual transfer: In the case of upper extremity skill acquisition, the transfer of skill from one upper limb to the contralateral upper limb.

Occupationally-embedded performance: Performance that results from participation in a meaningful and purposeful activity.

Occupational therapy: health profession that is concerned with facilitating functional living and improving functional performance.

Purpose of the Study

The purpose of the present study was to examine further the issue of intermanual transfer in an occupationally embedded performance. For the novel task, we chose writing a non-native (East Indian) alphabet letter as an occupationally embedded performance. Writing by itself is an occupation. We assumed that learning to write a non-native alphabet letter would increase the meaningfulness of the task to the participants. Participants were trained to write the alphabet with their right or left hand. We hypothesized that there would be an asymmetry in the direction of transfer from right to left for the spatial properties and an asymmetry in the direction of transfer from left to right for the temporal properties. We also assumed that the transfer advantage in any direction would be greater than the findings of previous studies due to the use of occupationally embedded task performance.

Chapter 2 Literature Review

Motor Learning

The ability of the brain and the body to work together to perform purposeful motor acts is a principle in occupational therapy theory. The development of general strategies used to solve movement problems in a variety of contexts is known as motor learning. Recently there have been a number of studies drawing parallels between motor learning principles and occupational and physical therapy practice (Burgess, 1989; Carr & Shepherd, 1989; Crutchfield & Barnes, 1993; Ferguson & Trombly, 1997; Glickstein & Hudak, 1999; Hanlon, 1996; Jarus, 1994; Poole, 1991; Sabari, 1991). For example, motor learning is based upon the brain's ability to store general strategies that enable a person to perform specific motor acts in a multitude of environmental contexts. Similarly, a major identity of the profession of occupational therapy is the ability to facilitate a person's functional abilities in all aspects of life.

Motor learning provides answers for how skilled movement and proficiency develop. Occupational therapists use the stages of motor learning to enhance the outcome of their services. The stages of motor learning are skill acquisition, retention, and transfer. These stages are not sharply defined; a person can be in more than one stage simultaneously. Skill acquisition is the stage of motor learning when the learner acquires the skill; anything that is done by the learner to enhance the learning process and the ability to perform the skill is included here (Shea, Shebilske & Worchel, 1993). Retention of a skill is the ability of the learner to perform the skill after it has been acquired and the immediate effects of practice have faded (Schmidt, 1991). Skill transfer is the focus of this present research study. The ability of the learner to perform the skill in another context, using different materials, equipment, or body parts is known as transfer of skill (Schmidt, 1991).

Motor learning and its stages have important implications in occupational therapy. Occupational therapists use aspects of each of the stages when planning clinical treatments. Skill acquisition is incorporated into treatment by the use of materials, environment, design of the activity, and even therapeutic self. Anything the therapist does to enable the client to succeed at the chosen occupation incorporates the skill acquisition principles of motor learning into treatment. In occupational therapy, retention of skill is the person's ability to perform the skill or occupation even after therapy has ended. A major emphasis for occupational therapy practitioners when working with their clients is independent living, which is possible with the retention of skills learned or relearned in therapy.

One important goal of occupational therapy treatment is the person's ability to generalize or transfer skills learned in one context to another. When the person has acquired and retained the skills needed, transfer of performance to other situations is possible. For example, when a client who has suffered a stroke learns to put on a shirt in the rehabilitation clinic, the next step is to increase the scope of performance so that the skill may transfer to other settings such as the home, and to using other types of shirts.

There are many theories about motor learning, about how and why it occurs (Shea, et al., 1993). The theories have emerged over time. Motor learning has been explained through such theories as the reflex theory (Magnus, 1926; Sherrington, 1906) and the hierarchical theory (Schmidt, 1988). In these theories, the central nervous system is thought to be organized by the higher cortical levels imposing control over lower levels to restrict or allow movements. Thus, the motor learning abilities are affected by the maturation of the central nervous system (Gesell, 1954). Other theories (Crutchfield and Barnes, 1993; Horak, 1991) hold that movement is the result of the person's interaction with the environment through a systems approach. Therefore, there are many factors affecting and contributing to the motor performance. The top-down hierarchical organization of the central nervous system has been compared to an organization of parallel pathways of communication. The motor learning theories compare the idea that the cortical levels exert control over the motor output, with the consideration that there are many more factors in the environment and in the person's sensory system that impact learning.

Motor learning has been viewed two different ways: First, changes in motor performance during the acquisition stage were considered reflective of learning. In this view, anything that adjusted the performance during acquisition was thought to be essential to improving motor learning. In the second view, the performance changes that occur during the acquisition stage are considered transient and not reflective of learning. Retention or transfer tests are used to evaluate motor learning in this view. When the performer is tested after the temporary results of the acquisition stage have diminished, consistent changes in the capacity of motor learning retention are measured (Mathiowetz & Haugen, 1994).

Transfer of Learning

A motor skill is usually learned through specific body parts and in specific settings. As the proficiency of skill performance develops, the learner begins to generalize the skill and can perform the skill in a different setting utilizing a different limb. For example, a person learns to write on paper using small joint movements of the hand. Once acquired, the person can transfer this skill to larger joints, as when writing on a blackboard using shoulder movements. This is called transfer of skill learning. Occupational therapy's overall goal is the transfer of skill so that the person can function in more than one specific setting.

During motor learning or retraining, it is important not only that the client be able to retain the skill acquired, but also be able to transfer that skill to a different context or setting. As for example, when a client with unilateral stroke is relearning to dress in a hospital setting, it is expected that the client will be able to use the dressing techniques learned and apply them at home and to different types of clothing. This is called contextual transfer of motor learning (Schmidt, 1991). Context transfer occurs when the skill stays the same but the environment or situation changes. An example is the transfer from writing at a desk to writing on a blackboard. The skill of writing does not change. The place in which the writing occurs has changed from a horizontal to a vertical position. The limb components used in the writing task have also changed from small joint movements of the hand to large joint movements of the shoulder.

Motor learning research suggests that transfer of motor learning can also occur from the portion of the limb used in practice to the opposite, unpracticed limb. It has long been documented that there is some degree of facilitation in the acquisition of a motor task by an unpracticed hand, if that motor task has been practiced and acquired previously by the other hand (Parlow & Dewey, 1991). This is called intermanual transfer or lateral transfer of motor learning. In other words, this means that the effect of training given to one hand can be carried over to the other hand (Imamizu & Shimojo, 1995). The skills that are able to transfer in such a manner are unilateral skills. Unilateral skills are motor skills used in various activities of daily living, work, or leisure that require performance on only one side of the body. Examples include playing darts, writing, and so on. The skill of each of these occupations can be performed moderately well by either hand or arm in persons without disruption of function in either upper extremity. As in the skill of handwriting, a person acquires this skill through his/her dominant hand. However, if the person tries to reproduce a segment of handwriting with the non-dominant hand, the writing will still be identifiable as unique to that person despite obvious degrading in the quality of the writing. Therefore there will be some invariant characteristics associated with the performance that is identifiable with the skill. The invariant characteristics of motor skill transfer, consisting of spatial and temporal properties of movement, gave rise to the theory of generalized motor program (Schmidt, 1988). An essential component of this theory is that the learning of a skill is goal specific rather than specific to limb or context (Kaluzny, Palmeri, & Wiesendanger,1994) and therefore transfer to a different context or limb is possible.

Intermanual Transfer

Recently there has been an interest in intermanual transfer (Charron, et al., 1996; Hoshiyama & Kakigi, 1999; Imamizu & Shimojo, 1995; Kaluzny, et al., 1994; Sathian & Zangaladze, 1998; Stoddard & Vaid, 1996; Thut, et al., 1996; Thut, et al., 1997). These studies present evidence that transfer occurs between the hands but the exact nature of transfer is not known.

The principle cause of intermanual transfer has been attributed to the efficiency of the information exchange in the brain between the two cerebral hemispheres by commissural fibers in the corpus callosum (Hoptman & Davidson, 1994; Thut, et al., 1997a). Through this inter-hemispheric communication of information, one cerebral hemisphere remotely facilitates or inhibits the other cerebral hemisphere (Hoshiyama & Kakigi, 1999;Thut, et al., 1999). This is extremely intriguing to the occupational therapy perspective when working with clients who are affected on one side of the body due to stroke or amputation. The transfer of skills from one cerebral hemisphere to the other has tremendous possibilities for the recovery of function on the affected side and also for the increase of functioning on the non-dominant unaffected side. To be able to use the knowledge of transfer between cerebral hemispheres would be an insight into recovery of function.

A few studies, attempting to understand the nature of intermanual transfer, have found that the direction of transfer exchange between cerebral hemispheres is asymmetric rather than symmetric (Edwards & Elliot, 1989; Parlow & Kinsbourne, 1990; Stoddard & Vaid, 1996). An asymmetrical direction of transfer results when the transfer advantage, or benefit of skill exchanged from one side to another, is not one hundred percent but degrades during the transfer. These studies have found that such asymmetry is not uni-directional, rather it is bi-directional. Therefore, when looking at the transfer advantage to the dominant hand versus to the non-dominant hand, inconclusive results have been obtained. For example, some researchers, by using a variety of sensorimotor and visuomotor tasks such as writing (Hoshiyama & Kakigi, 1999), tapping (Edwards & Elliot, 1989), and tactile recognition (Parlow & Kinsbourne, 1989; Sathian & Zangaladze, 1998) that have different spatial and temporal characteristics like timing, shape, and position have found a left-hand advantage over the right hand in relearning the skill (Halsband, 1992; Laszlo, et al., 1970; Parlow & Kinsbourne, 1989) while others have found a right-hand advantage over the left hand in relearning a skill in right handers (Hicks, 1974; Taylor and Heilman, 1980). Thus it might appear that transfer advantage is not guided by handedness but rather by task characteristics.

A model has been proposed to explain the discrepancy of transfer advantage that is associated with the exchange of information through the corpus callosum in regards to motor learning. This model is known as the cross activation model (Parlow & Kinsbourne, 1989). According to this model, it is assumed that whenever a novel skill is learned, a dual motor memory (engram) is formed in both cerebral hemispheres irrespective of the hand used to acquire the skill. Thus the directional advantage of transfer may depend on the spatio-temporal characteristics of the motor task since there is a known difference between hemispheric processing of such information. For example, the right hemisphere is superior to the left in processing spatial (amplitude or accuracy) properties while the left hemisphere is superior to the right in processing motoric (temporal or sequential) properties of an object. Therefore it can be reasonably assumed that the left hand will have a benefit of transfer in the re-acquisition of the spatial properties of a task over the right hand because of the direct control the right hemisphere has over the left hand. Conversely, the right hand will have a benefit of transfer in the re-acquisition of the motoric properties of a task over the left hand because of the direct control the left hemisphere has over the right hand. Thereby, the transfer advantage appears to be related to the goal (task characteristics) rather than the limb (handedness). This is supported by the cross activation model, and also relates the scope of occupational therapy with the concept of intermanual transfer.

In the occupational therapy literature, it has been reported that an occupationally embedded movement is smoother and more efficient than rote exercise or a non-meaningful task (Nelson, et al., 1996; Ross & Nelson, 1998; Wu, et al., 1994;). Incorporating the knowledge of intermanual transfer into the therapeutic practice of occupational therapy can be used in the regaining or retraining of skills disrupted following unilateral damage to the brain, as in stroke patients. Therefore through the exchange of information between cerebral hemispheres, the motor engrams stored in the opposite, unaffected cerebral hemisphere can be accessed and transferred to some degree to the affected cerebral hemisphere. The amount and nature of such transfer is unknown. Intermanual transfer of motor learning has significant relevance to the specificity of clinical motor training activities used in therapy. Increased knowledge about the neurological transfer capabilities for learned motor movements will assist clinical practitioners to develop more effective therapeutic strategies to be used with motor disabled clients. Integral to this premise is the notion that clients can learn or relearn to perform motor behaviors by accessing previously learned skills from the contralateral cerebral hemisphere.

Previous studies in the area of intermanual transfer have produced variable results. For example, in the research studies examined, various task requirements were used (Edwards & Elliot, 1989; Imamizu & Shimojo, 1995; Parlow & Kinsbourne, 1990; Sathian & Zangaladze, 1998; Stoddard & Vaid, 1996; Thut, Cook, Regard, Leenders, Halsband & Landis, 1996). Different spatial and temporal constraints such as shape (Stoddard & Vaid, 1996), position of task (Imamizu & Shimojo, 1995), and emphasis on speed (Thut, et al., 1996) were imposed on subjects during transfer of learning between hands. Thus, discrepancies in transfer advantage have resulted.

In 1995, Imamizu and Shimojo conducted a study in which visual-motor learning and intermanual transfer were explored. The path the hand took to reach the desired location was compared to the actual joint positions in the arm during the reaching task. During analysis of the data, the factor of time was used to determine occurrence of learning. The researchers found significantly greater transfer from right to left than from left to right, however the transfer was nearly 100% regardless of direction.

The method of analyzing the transfer between hands by researching the effects of one-sided practice of motor skills on the opposite side's performance has been established by Thut, et al. (1996). Thut, et al. (1996) examined the effects of original learning by one hand and the transfer effects to the other hand. In this study, subjects drew meaningless figures on a piece of paper in between two specified parallel lines with either their left or right hand as a measure of original learning. To compare original learning and transfer learning, subjects then drew, with the opposite hand, the vertical reversals of the figures drawn during original learning (Thut, et al., 1996). Accuracy and speed were emphasized to the subjects. Results concluded a gain in accuracy when the direction of transfer was from left to right (Thut, et al., 1996).

Stoddard and Vaid (1996) studied transfer learning asymmetries in a finger maze task. Three variables observed by the researchers were handedness, hand used during acquisition, and orientation of the maze during transfer. The experimenter blind-folded the subjects and led one of the subject's fingers through the course of the maze. Subjects were divided into acquisition groups randomly, that is, the group that learned the maze with their right hand was comprised of both right- and left-hand dominant subjects. Therefore, the handedness related effects were minimized. For those subjects who used their right hand at acquisition, left hand transfer performance during identical and vertically reversed mazes was increased over performance on a mirror-reversed maze. For those subjects who used their left hand at acquisition, right hand transfer performance on the vertically reversed and mirror-reversed mazes was better than performance on the identical maze. According to the researchers, different learning strategies are used during acquisition by the left and the right hand despite hand dominance.

Sathian and Zangaladze (1998) studied intermanual transfer in a perceptual learning task. Subjects' right index fingerpads were used for acquisition of the task. The perceptual learning task consisted of subjects' using the fingerpad to discriminate between two different patterns of three dots. Researchers noted that the transfer to the left index fingerpad was nearly one hundred percent. The researchers also studied the retention of task acquisition by evaluating the subjects' performance on the same task several months later. Practice effects were still present, evidenced by fewer practice sessions required to reach the final threshold values in the initial experiment.

The researchers claim their results indicate:

"perceptual learning in tactile hyper-acuity is not location specific but, rather, transfers readily between hands. The intermanual transfer suggests that these learning effects involve brain regions where corresponding body part representations are inter-hemispherically connected" (p.133).

The involvement of brain regions that are inter-hemispherically connected supports the cross-activation model (Parlow & Kinsbourne, 1989), a theory attempting to provide answers to the questions of intermanual transfer.

These studies (Imamizu & Shimojo, 1995; Sathian & Zangaladze, 1998; Stoddard & Vaid, 1996; Thut, et al., 1996) show the variability of results concerning the direction of transfer advantage. Some studies found no difference in direction of transfer advantage (Imamizu & Shimojo, 1995), some studies found a left to right transfer advantage (Thut, et al., 1996), while others found a right to left transfer advantage (Sathian & Zangaladze, 1998). The answer to the question of the exact nature of intermanual transfer remains unresolved. Increased knowledge of the neurological transfer possibilities for learned movements might assist clinical practitioners in developing more effective therapeutic strategies used with motor disabled patients. Integral to this premise of intermanual transfer is the notion that clients can learn or relearn to perform motor behaviors by accessing previously learned skills from the relatively unaffected contra-lateral cerebral hemispheres.

Summary

The term skill has many definitions. A motor skill is any movement that requires practice to gain proficiency in the movement. In occupational therapy, activities of daily living, or the occupations that we perform throughout the day, are composed of learned skills. Using chopsticks to eat a meal and riding a bicycle are examples of skills. To be able to perform these skills efficiently, the performer is required to have practiced repeatedly. The process by which we acquire these skills is called motor learning (Schmidt, 1988).

Occupational therapists are concerned with their client's motor learning abilities. The client's ability to transfer skills learned in therapy sessions into their everyday life situations and environments is often a major goal of rehabilitation hospitals. One group of individuals that occupational therapy practitioners service are the individuals who have suffered a stroke. A stroke occurs when there is a blockage of an artery in the brain. Blood flow in the brain is cut off beyond the blockage point. Some deficits that can occur following a stroke include marked one-sided weakness and sensory loss. According to Glickstein & Hudak (1999), "the motor learning approach to treatment is now the recommended approach to rehabilitation after stroke" (p.9). As in this example, when disability effects one side of the body, unilateral skills are relearned with the able hand. Knowledge of the base skills retained and available during transfer whether to the non-disabled side or to the disabled side has implications for the structure of occupational therapy treatment.

The present study deals with intermanual transfer of a novel writing task. A novel task was chosen so that previous experience with the task could be ruled out when analyzing transfer results. Motor learning of the dominant and non-dominant hand and how transfer of such learning affects performance has implications in occupational therapy. If, as research suggests, there is an increased performance by the transfer of motor learning from one hand to the other, then motor learning is not occurring in the body part but rather is being stored in the brain. This has value in that the motor program can be carried out by any part of the body as long as it is stored in the brain.

Chapter 3 Methodology

The purpose of this study was to assess the nature and degree of intermanual transfer for a novel writing task in normal subjects. The objectives were to:

- record the excursion of pen movement over time during the novel writing task,
- record the electromyography response from the first dorsal interosseus muscle as an indicator of muscle involvement,
- derive the kinematic variables of duration (time) and amplitude of pen movements from the time series record of pen movements,
- and compare the kinematic variables of pen movements produced by left and right hands.

Research Questions

Two questions asked by the study were:

In right handed subjects,

- what is the nature of intermanual transfer of a novel skill to the left hand that results from skill acquisition through right-hand practice (the dominant to non-dominant transfer).
- what is the nature of intermanual transfer of a novel skill to the right hand that results from skill acquisition through left hand practice (the non-dominant to dominant transfer).

Assumptions

The following assumptions were made as part of the investigation:

- The Bengali alphabet letter was a novel task to participants of the study,

- The subjects would find the task meaningful to learn,
- The subjects did not have any motor learning disabilities that would impede their performance,
- The population of Ithaca college students is a representative sample of the normal adult population,
- Pen movements represent the composite movements of the fingers and are therefore an objective measure of motor learning,
- Electromyography response from the first dorsal interosseus muscle is representative of the pen grip,
- And subjects truthfully responded when they were asked about their handedness and about past neurological or orthopedic abnormalities.

Participants

Ten (7 female and 3 male) healthy persons voluntarily participated in the present study. The participants were assumed healthy when they reported that they were devoid of any neurological or orthopedic conditions, and showed no psychopathological symptoms, and were not under treatment by a physician at the time of the present study. The mean age of the participants was 22.8 years (SD=0.7 years). Participants were students in the School of Health Sciences and Human Performance at Ithaca College at the time of this study. The study was approved by the Ithaca College human subject research committee prior to experimentation. Each subject signed an informed consent form prior to participation and no incentives were given for participation (Appendix A2). All participants were right handed according to self-report.

Apparatus

All tests were performed in the motor control laboratory of the Ithaca College occupational therapy department. In the motor control laboratory the staging area included: a table, a chair for the participants, a 60 degree inclined writing platform, an inkless pen, and sketches of the foreign alphabet letter.

A movement analysis system, the search coil measurement system made by Neumann, Germany, along with the data collection software, AutoLab (Version 2.2), were used to collect the data on-line. Further off-line analysis of data was done by Origin analytical Software (Version 5.5). The coil measurement system works similarly to the optotrek camera recording system and is being used by others to record limb or object movements in space (Hore, Ritchie, & Watts, 1999; Hore, Watts, Tweed, & Miller, 1996). In the coil measurement system the sensors are tiny coils (~ 2 cm in diameter) that can be attached to the moving limbs or objects. A large external field coil (2 meters x 2 meters) is used to create an electromagnetic field of low radio frequency (70-120 kHz) and the receiver coils receive and emit this frequency upon induction. The amplitude of the emitting signal by a receiver coil is directly proportional to their angular orientation in space and can be calibrated to an angular measurement in degrees. Therefore, using the system one can faithfully measure angular movements of a moving object or limb over time. One advantage of this system is that the sensors can be attached anywhere, in contrast to optical sensors (reflective marker) used in the optotrek system where the sensors have to be in the line of view of the camera. In the present study, one sensor coil was attached to the top of the pen to record the pen's forward and backward movements during the task. Movement data were collected and digitized at 1000 points per second (sample rate: 1000 Hz).

Experimental Procedure

Participants were seated comfortably in a chair in front of the writing table and asked to write the foreign alphabet letter on a writing platform that was inclined 60 degrees vertically. Pilot experiments revealed that angular front-to-back movements of the pen were much more pronounced in the inclined platform compared to the flat platform of the table and thus aided in the recording procedure. In the learning task, participants wrote using their preferred writing grasp while the non-writing hand was placed on the forearm of the writing hand to prevent movement at the wrist and upper arm involvement (See Figure 1). Participants were asked to write the letter as quickly and as accurately as possible. Each participant traced the foreign alphabet letter six times for practice learning, (PL). For the practice learning and original learning the same hand was used. The original learning, (OL), task involved drawing the foreign alphabet letter with the practiced hand between two horizontal lines one inch apart on a blank sheet of paper ten times without any visual cue. For assessing transfer to the contralateral untrained extremity, upon visual inspection of the vertical reversal of the letter the participants reproduced the reversal ten times (transfer learning, TL). According to Thut, et al., (1996), this could avoid the demands of mental rotation by the central nervous system. The mirror reversal of the task was used to preserve the same contralateral muscle involvement (Thut, et al., 1996).

The study was a counterbalanced repeated measures design where each subject performed as his or her own control across the conditions. Prior to testing, each participant was given time and instruction to become familiar with the task. After he/she verbalized understanding of the task, each participant was assigned to the conditions: (a) right original learning to assess distal transfer learning from right-to-left direction, and then (b) left original learning to assess distal transfer learning from left-to-right direction.

In between conditions, the participants were allowed rest time as requested.

Data Reduction and Analysis

The independent variables in the present study were the two different conditions as mentioned above. The dependent variables were: (a) the displacement of the pen in degrees, and (b) the movement time or duration of the task.

Displacement of the pen was directly recorded by the measuring instrument and was converted into degrees by software that was calibrated before each experimental session. The duration of movement time was calculated by measuring the time between initiation and termination points of the movement and was measured from the velocity curve of the movements. Velocity curves of the movements were obtained by digitally differentiating the displacements or position curve of the movement over time. Initiation and termination points of a movement were taken as points where the velocity reached 5% of the peak velocity. The peak velocity was determined as the maximum velocity within a single movement. Measurements of significant differences in motor condition parameters between original learning and transfer learning were assessed through the use of paired t-tests. A paired t-test is appropriate for this type of design with two observations on the repeated factor (Dawson-Saunders and Trapp, 1994, p. 107).

References

Abdulwahab, S. S. (1996). Physical disability in patients with hemiparesis. *International Journal of Rehabilitation Research, 19*, 157-161.

Bakkes, E. S., Groenewald, S. J., & Hughes, J. R. (1996). The use of functional activities in therapy: An integration of the principles of motor control and the learning process. *South African Journal of Physiotherapy, 52*, 33-36.

Blake, P. F., & Fritz, V. U. (1996). Functional outcome of the upper limb after stroke. *South African Journal of Physiotherapy, 52*, 40-42.

Brown, S. H., & Cooke, J. D. (1986). Initial agonist burst is modified by perturbations preceding movement. *Brain Research, 377*, 311-22.

Burgess, M. K. (1989). Motor control and the role of occupational therapy: Past, present, and future. *The American Journal of Occupational Therapy, 43*, 345-348.

Carr, J. H., & Shepherd, R. B. (1989). A motor learning model for stroke rehabilitation. *Physiotherapy, 75*, 372-380.

Castiello, U., & Stelmach, G. E. (1993). Generalized representation of handwriting: Evidence of effector independence. *Acta Psychologica, 82*, 53-68.

Charron, J. F., Collin, I., & Braun, C. M. (1996). Intermanual transfer of somaesthetic information: A two-point discrimination experiment. *Neuropsychologia, 34*, 873-877.

Cobas, A., & Arbib, M. (1992). Prey catching and predator - avoidance in frog and toad: Defining the schemas. *Journal of Theory and Biology, 157*, 271-304.

Crutchfield, C. A., & Barnes, M. R. (1993). *Motor control and motor learning in rehabilitation.* Atlanta: Stokesville.

Dawson-Saunders, B., & Trapp, R. G. (1994). *Basic and clinical biostatistics*. 2nd Ed. Norwalk, CT: Appleton & Lange.

Dimond, S. J., Scammell, R., Pryce, I. J., Huws, D., & Gray, C. (1980). Some failures of intermanual and cross-lateral transfer in chronic schizophrenia. *Journal of Abnormal Psychology, 89*, 505-509.

Edwards, J. M., & Elliot, D. (1989). Asymmetries in intermanual transfer of training and motor overflow in adults with Down's syndrome and nonhandicapped children. *Journal of Clinical and Experimental Neuropsychology, 11*, 959-966.

Ferguson, J. M., & Trombly, C. A. (1997). The effect of added-purpose and meaningful occupation on motor learning. *The American Journal of Occupational Therapy, 51*, 508-515.

Gesell, A. (1954). The ontogenesis of infant behavior. In L. Carmichael (Ed.), *Manual of child psychology*. 2nd Ed. (p.335-373). New York: Wiley.

Glickstein, J., & Hudak, M. T. (1999). Pathophysiology of stroke: A motor learning approach to treatment. *Focus on Geriatric Care and Rehabilitation, 13*, 1,3-11.

Gliner, J. A. (1985). Purposeful activity in motor learning theory: An event approach to motor skill acquisition. *The American Journal of Occupational Therapy, 39*, 28-34.

Hall, B. A., & Nelson, D. L. (1998). The effect of materials on performance: A kinematic analysis of eating. *The Scandinavian Journal of Occupational Therapy, 5*, 69-81.

Halsband, U. (1992). Left hemisphere preponderance in trajectorial learning. *Neuro Report*, *3*, 397-400.

Hanlon, R. E. (1996). Motor learning following unilateral stroke. *Archives of Physical Medicine and Rehabilitation*, *77*, 811-815.

Hicks, R. E. (1974). Asymmetry of bilateral transfer. *American Journal of Psychology*, 87, 667-674.

Horak, F. B. (1991). Assumptions underlying motor control for neurologic rehabilitation. In M. J. Lister (Ed.), *Contemporary management of motor control problems: Proceedings of the II STEP Conference* (p.11-27). Alexandria, VA: Foundations for Physical Therapy.

Hore, J., Ritchie, R., & Watts, S. (1999). Finger opening in an overarm throw is not triggered by proprioceptive feedback from elbow extension or wrist flexion. *Experimental Brain Research, 125*, 302-12.

Hore, J., Watts, S., Tweed, D., & Miller, B. (1996). Overarm throws with the non-dominant arm: kinematics of accuracy. *Journal of Neurophysiology*, *76*, 3693-704.

Hoptman, M. J., & Davidson, R. J. (1994). How and why do the two cerebral hemispheres interact? *Psychological Bulletin*, *116*, 195-219.

Hoshiyama, M., & Kakigi, R. (1999). Changes in somatosensory evoked potentials during writing with the dominant and non-dominant hands. *Brain Research*, *833*, 10-19.

Imamizu, H., & Shimojo, S. (1995). The locus of visual-motor learning at the task or manipulator level: Implications from intermanual transfer. *Journal of Experimental Psychology: Human Perception and Performance*, *21*, 719-733.

Jackson, J. H., & Taylor, J. (Eds.). (1932). *Selected writings of John B. Hughlings, I and II*. London: Hodder & Stoughter.

Jarus, T. (1994). Motor learning and occupational therapy: The organization of practice. *The American Journal of Occupational Therapy*, *48*, 810-816.

Kaluzny, P., Palmeri, A., & Wiesendanger, M. (1994). The problem of bimanual coupling: A reaction time study of simple unimanual and bimanual finger responses. *Electroencephalography and Clinical Neurophysiology*, *93*, 450-458.

Kawamura, M., Hirayama, K., & Yamamoto, H. (1989). Different interhemispheric transfer of kanji and kana writing evidenced by a case with left unilateral agraphia without apraxia. *Brain*, *112*, 1011-1018.

Lacquaniti, F., Ferrigno, G., Pedotti, A., Soechting, J. F., & Terzuolo, C. (1987). Changes in spatial scale in drawing and handwriting: Kinematic contributions by proximal and distal joints. *The Journal of Neuroscience*, *7*, 819-828.

Laszlo, J. I., Baguley, R. A., & Bairstow, P. J. (1970). Bilateral transfer in tapping skill in the absence of peripheral information. *Journal of Motor Behavior*, *2*, 261-271.

Lee, T. D., Swanson, L. R., & Hall, A. L. (1991). What is repeated in a repetition? Effects of practice conditions on motor skill acquisition. *Physical Therapy*, *71*, 150-156.

Magnus, R. (1926). Some results of studies in the physiology of posture. *Lancet, 2,* 531-585.

Mandal, M. K., Singh, S. K., Asthana, H. S., & Srivastava, P. (1992). Bilateral transfer deficit in schizophrenia. *Comprehensive Psychiatry, 33,* 319-324.

Mathiowetz, V., & Haugen, J. B. (1994). Motor behavior research: Implications for therapeutic approaches to central nervous system dysfunction. *The American Journal of Occupational Therapy, 48,* 733-745.

Mathiowetz, V., & Wade, M. G. (1995). Task constraints and functional motor performance of individuals with and without multiple sclerosis. *Ecological Psychology, 7,* 99-123.

Mergl, R., Tigges, P., Schroter, A., Moller, H. J., & Hegerl, U. (1999). Digitalized analysis of handwriting and drawing movements in healthy subjects: Methods, results, and perspectives. *Journal of Neuroscience Methods, 90,* 157-169.

Nelson, D. L., Konosky, K., Fleharty, K., Webb, R., Newer, K., Hazboun, V. P., Fontane, C., & Licht, B. (1996). The effects of an occupationally embedded exercise on bilaterally assisted supination in persons with hemiplegia. *The American Journal of Occupational Therapy, 50,* 639-646.

Parlow, S. E., & Kinsbourne, M. (1989). Asymmetrical transfer of training between hands: Implications for interhemispheric communication in normal brain. *Brain Cognition, 11,* 98-113.

Parlow, S. E., & Kinsbourne, M. (1990). Asymmetrical transfer of braille acquisition between hands. *Brain and Language, 39,* 319-330.

Parlow, S. E., & Dewey, D. (1991). The temporal locus of training between hands: An interference study. *Behavior Brain Research*, *46*, 1-8.

Pedretti, L. W. (1996). *Occupational therapy: Practice skills for physical dysfunction. 4th Ed.* St. Louis, MO: Mosby-Year Book, Inc.

Petrovici, J. N. (1997). Interhemispheric transfer of learning in brain-damaged patients. *Journal of Neurosurgical Sciences*, *41*, 97-105.

Phillips, J. G., Gallucci, R. M., & Bradshaw, J. L. (1999). Functional asymmetries in the quality of handwriting movements: A kinematic analysis. *Neuropsychology*, *13*, 291-297.

Plamondon, R. (1993). Looking at handwriting generation from a velocity control perspective. *Acta Psychologica*, *82*, 89-101.

Poole, J. L. (1991). Application of motor learning principles in occupational therapy. *The American Journal of Occupational Therapy*, *45*, 531-537.

Punwar, A. J. (1994). *Occupational therapy: Principles and practice.* 2nd Ed. Baltimore, MD: Williams & Wilkins.

Raine, A., Andrews, H., Sheard, C., Walder, C., & Manders, D. (1989). Interhemispheric transfer in schizophrenics, depressives, and normals with schizoid tendencies. *Journal of Abnormal Psychology*, *98*, 35-41.

Ross, L., & Nelson, D. (2000). Comparing materials-based occupation, imagery-based occupation, and rote movement through kinematic analysis of reach. *The Occupational Therapy Journal of Research*, *20*, 45-60.

Sabari, J. S. (1991). Motor learning concepts applied to activity-based intervention with adults with hemiplegia. *The American Journal of Occupational Therapy, 45*, 523-530.

Sathian, K., & Zangaladze, A. (1998). Perceptual learning in tactile hyperacuity: Complete intermanual transfer but limited retention. *Experimental Brain Research, 118*, 131-134.

Schillings, J. J., Meulenbroek, R. G. J., & Thomassen, A. J. W. M. (1998). Functional properties of graphic workspace: Assessment by means of a 3D geometric arm model. *Acta Psychologica, 100*, 97-115.

Schmidt, R. A. (1988). *Motor control and learning: A behavioral emphasis*. Champaign, IL: Human Kinetics.

Schmidt, R. A. (1991). *Motor learning and performance: From principles to practice*. Champaign, IL: Human Kinetics.

Shea, C. H., Shebilske, W. L., & Worchel, S. (1993). *Motor learning and control*. Edgewood Cliffs, NJ: Prentice Hall.

Sherrington, C. S. (1906). *The integrative action of the nervous system*. New Haven: Yale University Press.

Smith, P. J. K., & Davies, M. (1995). Applying contextual interference to the Pawlata roll. *Journal of Sports Sciences, 13*, 455-462.

Stoddard, J., & Vaid, J. (1996). Asymmetries in intermanual transfer of maze learning in right- and left-handed adults. *Neuropsychologia, 34*, 605-608.

Taylor, H. G., & Heilman, K. M. (1980). Left hemisphere motor dominance in righthanders. *Cortex, 16*, 587-603.

Thut, G., Cook, N. D., Regard, M., Leenders, K. L., Halsband, U., Landis, T. (1996). Intermanual transfer of proximal and distal motor engrams in humans. *Experimental Brain Research, 108*, 321-327.

Thut, G., Halsband, U., Regard, M., Mayer, E., Leenders, K. L., & Landis, T. (1997a). What is the role of the corpus callosum in intermanual transfer of motor skills? A study of three cases with callosal pathology. *Experimental Brain Research, 113*, 365-370.

Thut, G., Roelcke, U., Nienhusmeier, M., Missimer, J., Maguire, R. P., Regard, M., Landis, T., & Leenders, K. L. (1997b). Intermanual transfer for training: Blood flow correlates in the human brain. *Behavioral Brain Research, 89*, 129-134.

Thut, G., Hauert, C. A., Morand, S., Seeck, M., Landis, T., & Michel, C. (1999). Evidence of interhemispheric motor-level transfer in a simple reaction time task: An EEG study. *Experimental Brain Research, 128*, 256-261.

Trombly, C. A. (1995). *Occupational therapy for physical dysfunction. 4th Ed.* Baltimore, MD: Williams & Wilkins.

Trombly, C. A., & Wu, C. Y. (1999). Effect of rehabilitation tasks on organization of movement after stroke. *The American Journal of Occupational Therapy, 53*, 333-343.

Van Den Heuvel, C. E., Van Galen, G. P., Teulings, H. L., & Van Gemmert, A. W. A. (1998). Axial pen increases with processing demands in handwriting. *Acta Psychologica, 100*, 145-159.

Viviani, P., & Terzuolo, C. (1982). Trajectory determines movement dynamics. *Neuroscience*, 7, 431-437.

Watson, D. E. (1997). *Task analysis: An occupational performance approach.* Bethesda, MD: American Occupational Therapy Association, Inc.

Winstein, C. J. (1991). Knowledge of results and motor learning - implications for physical therapy. *Physical Therapy*, *71*, 140-149.

Wu, C., Trombly, C., & Lin, K. (1994). The relationship between occupational form and occupational performance: A kinematic perspective. *The American Journal of Occupational Therapy*, *48*, 679-687.

Wu, C., Trombly, C. A., Lin, K., & Tickle-Degnen, L. (1998). Effects of object affordances on reaching performances in persons with and without cerebrovascular accident. *The American Journal of Occupational Therapy*, *52*, 447-56.

Yeun, H. K., Nelson, D., Peterson, C. Q., & Dickinson, A. (1994). Prosthesis training as a context for studying occupational forms and motoric adaption. *The American Journal of Occupational Therapy*, *48*, 55-61.

Chapter 4 Manuscript

Introduction

It has long been documented that there is some degree of facilitation in the acquisition of a motor task by an unpracticed hand, if that motor task has been practiced and acquired previously by the other hand (Parlow & Dewey, 1991). This is called intermanual or lateral transfer of motor learning. In other words, the effect of training given to one hand can be carried over to the other hand (Imamizu and Shimojo, 1995). This aspect of intermanual or lateral transfer of motor learning is somewhat overlooked in occupational therapy practice and literature; although a number of reports have appeared drawing parallels between motor learning principles and occupational and physical therapy practice (Burgess, 1989; Carr & Shepherd, 1989; Crutchfield & Barnes, 1993; Ferguson & Trombly, 1997; Glickstein & Hudak, 1999; Hanlon, 1996; Jarus, 1994; Poole, 1991; Sabari, 1991). These reports are focused mainly on the issue of practice learning that occurs during skill acquisition and feedback conditioning (effect of feedback) during practice.

The concept of intermanual transfer has important implications in therapeutic practice as knowledge of skill transfer potential can be utilized in regaining or retraining some of the skills disrupted following unilateral damage to the brain as may occur with a stroke or a unilateral dominant hand amputation (Jarus, 1994). This may allow occupational therapy recipients to efficiently regain control over injured muscles or relearn skills through the use of functional activities by taking advantage of the already learned skills of the uninjured or relatively unaffected side of the body. The present study deals with intermanual transfer of motor learning.

Intermanual Transfer

Intermanual transfer has been attributed to the efficiency of the information exchange between the two cerebral hemispheres via commissural fibers in the corpus callosum (Hoptman & Davidson, 1994; Thut, et al., 1997a). Through this interhemispheric channeling of information, one hemisphere remotely facilitates or inhibits the other hemisphere, as observed in evoked potential or cerebral blood flow studies (Thut, et al., 1999). A few studies examined the nature of intermanual transfer have found that the direction of such transfer exchange is asymmetric rather than symmetric (Edwards & Elliot, 1989; Parlow & Kinsbourne, 1990; Stoddard & Vaid, 1996). In other words, the transfer advantage or benefit of skill exchanged from one side to another is not complete, rather it degrades during the transfer. These studies have also found that such asymmetry is not uni-directional, rather it is bi-directional. Using a variety of sensorimotor and visuomotor tasks that have different spatial and temporal characteristics, some researchers found a left-hand advantage over the right hand (Halsband, 1992; Laszlo, et al., 1970; Parlow and Kinsbourne, 1989) while others have found a right-hand advantage over the left hand in relearning a skill in right handed subjects (Hicks, 1974; Taylor and Heilman, 1980).

In an attempt to explain this discrepancy of transfer advantage a model has been proposed and is known as the cross activation model (Parlow & Kinsbourne, 1989). According to this model, it is assumed that whenever a novel skill is learned a dual motor memory (engram) is formed in both the cerebral hemispheres irrespective of the primary hand used to acquire the skill. The nature of the engram, however, differs in right and left hemispheres. Different attributes of a task are stored differentially in either right or left hemisphere because of the known differences in function between right and left hemispheres. For example, the right hemisphere is superior to the left hemisphere in processing spatial (amplitude or accuracy) properties and the left hemisphere is superior to the right hemisphere in processing motoric (temporal or sequential) properties of a task (Gazzaniga, 1998; Sperry, 1974, 1982). Thus, the directional advantage of transfer may depend on the spatio-temporal characteristics of the motor task. Therefore, it can be reasonably assumed that the left hand will have a benefit of transfer in the re-acquisition of the spatial properties of a task over the right hand because of the direct control the right hemisphere has over the left hand. Conversely, the right hand will have a benefit of transfer in the re-acquisition of the motoric properties of a task over the left hand because of the direct control of the left hemisphere over the right hand.

Asymmetry of transfer advantage may also depend on the participant's perception of the task. Occupational therapy research has demonstrated that a task which a client perceives as meaningful and purposeful will elicit better movement production and learning than a non-purposeful task (Nelson, et al.,1996; Ross & Nelson, 2000; Wu, et al., 1994). In other words, an occupationally embedded movement is smoother and more efficient than a rote exercise or non-meaningful task. Studies examining the effect of purpose on quality of movement have not examined intermanual transfer. In addition, studies examining intermanual transfer have generally used meaningless motor tasks (Thut, et al., 1996; 1997a). Therefore, it is important to extend the occupational therapy research to examine asymmetry of transfer in the context of a meaningful task.

Kinematic Analysis

One way to measure a motor performance is to analyze the kinematic parameters of movement made during a motor act. A number of studies are reported in the occupational therapy literature based on kinematic analyses of movement (Hall & Nelson, 2000; Mathiowetz and Wade, 1995; Wu, et al., 1994; Wu, et al., 1998). Readers are referred to these studies for a detailed discussion of kinematic analysis of movement. In the kinematic analysis of movement, the movement parameters over time are recorded by attaching markers or sensors to the moving body parts. Two important parameters to consider are the amplitude of the movement and the duration of the movement apart from the velocity profile (Brown & Cooke, 1986). Movement amplitude represents the extent of excursion of a limb through space and is expressed in degrees; this is similar to measurements of range of motion. Duration of a movement refers to the time taken by the movement from start to finish and is expressed as either milliseconds or seconds. Movement amplitude made under the emphasis of accuracy reflects the spatial properties of the movement while the duration of a movement reflects the temporal properties of a movement (Thut, et al., 1996). Researchers may also record the associated muscular response during a movement by means of surface electromyography (EMG). When EMG from a relevant muscle is recorded in synchrony with an associated movement, EMG can then serve as a window to understand the nature of brain programming (Brown & Cooke, 1986).

Present Study

In this study we attempted to examine further the issue of intermanual transfer in an occupationally embedded performance. We argued that an occupationally embedded task would produce a greater transfer than the use of a meaningless task as used in earlier intermanual transfer literature. For the novel upper extremity learning task, we chose writing a non-native (East Indian) alphabet letter as an occupationally embedded performance. Writing by itself is an occupation. We assumed that learning to write a non-native alphabet would increase the meaningfulness of the task to the participants. We hypothesized that there would be an asymmetry in the direction of transfer from right to left for the spatial properties and an asymmetry in the direction of transfer from left to right for the temporal properties. We also assumed that asymmetry in the transfer advantage under any direction would be minimal because of the use of occupationally embedded performance.

Methods

Participants

Ten (7 female and 3 male) healthy persons voluntarily participated in the present study. Participants were recruited through the use of flyers advertising the study; interested subjects contacted the researchers. The participants were assumed healthy when they reported that they were devoid of any neurological or orthopedic conditions, showed no psychopathological symptoms and were not under treatment by a physician at the time of the study. Mean age was 22.8 years (SD=0.7 years). Participants were students in the School of Health Sciences and Human Performance at Ithaca College at the time of this study. The study was approved by the Ithaca College human subject research committee prior to experimentation. Each subject signed an informed consent form prior to participation and no incentives were given for participation. All participants were right handed according to self-report.

Apparatus

All tests were performed in the motor control laboratory of the Ithaca College occupational therapy department. In the motor control laboratory the staging area included a table, a chair for the participants, a 60 degree inclined writing platform, an inkless pen, and sketches of the foreign alphabet letter drawn on paper. The size of the sample letter was 2 cm. (Figure 1). The movement analysis system, a search coil measurement system made by Neumann, Germany, along with the data collection software AutoLab (Version 2.2), were used to collect the data on-line. Further off-line analyses of data were done by Origin analytical Software (Version 5.5).

The coil measurement system works similarly to the optotrek camera recording system and is being used by others to record limb or object movements in space (Hore, Ritchie, & Watts, 1999; Hore, Watts, Tweed, & Miller, 1996). One advantage of the search coil system is that the sensors can be attached anywhere, in contrast to optical sensors (reflective marker) used in the optotrek system, where the sensors have to be in the line of view of the camera. In the coil measurement system the sensors are tiny coils (~ 2 cm in diameter) that can be attached to the moving limbs or objects. A large external field coil (2 meters x 2 meters) is used to create an electromagnetic field of low radio frequency (70-120 kHz) and the receiver coils receive and emit this frequency when an electric current is produced by the proximity of an electric or magnetic field. The amplitude of the emitting signal by a receiver coil is directly proportional to the coil's angular orientation in space and can be calibrated to angular measurement in degrees. Therefore, using the system one can faithfully measure angular movements of a moving object or limb over time. In this study, one sensor coil was attached to the top of the pen to record the pen's forward and backward movements during the task (Figure 1). Movement data were collected and digitized at 1000 points per second (sample rate: 1000 Hz).

To detect muscle activity during the task of writing, non-invasive surface electromyography (EMG) was recorded from the first dorsal interosseus muscle of hand. The Bagnoli EMG system was used. The EMG electrodes were placed on the muscle belly (Figure 1). EMG data were collected and digitized at 1000 points per sec (sample rate: 1000 Hz). Raw EMG signals were bandpass filtered, half-wave rectified and smoothed according to standard procedure (Brown & Cooke, 1986) for further analysis.

Experimental Protocol

Participants were seated comfortably in a chair in front of the writing table and asked to write the foreign alphabet letter on a writing platform that was inclined 60 degrees vertically. Pilot experiments revealed that angular front-to-back movements of the pen were much more pronounced in the inclined platform compared to the flat platform of the table and thus aided in the recording procedure. Participants were asked to write the letter as quickly and as accurately as possible. In the learning task, participants wrote using their preferred writing grasp while the non-writing hand was placed on the forearm of the writing hand to prevent movement of the upper arm. Wrist movements of the non-writing hand were avoided by wearing an adjustable wrist immobilization brace (Figure1). First, the participants practiced tracing the foreign alphabet letter 6 times to acquire the learning with either their left or right hand. This is called practice learning (PL). Pilot experiments showed that six tracings of the letter was enough for learning. Thut, et al., (1996) also used six trials for their participants during practice of drawing meaningless figures. Following completion of PL, participants reproduced the learning with their practice hand ten times between two horizontal lines 2 cm apart on a blank sheet of paper. This was called original learning (OL). Participants used an inkless pen to control the visual feedback the ink would have provided. To assess transfer to the contralateral untrained extremity, the participants reproduced the vertical mirror reversal of the same letter ten times with their contralateral hand. This is called transfer learning (TL). The mirror reversal of the task was used to preserve the same contralateral muscle involvement (Thut, et al., 1996). During transfer learning the reversal image of the letter was presented for visual inspection. According to Thut, et al., (1996), this could avoid the demands of mental rotation by the central nervous system.

The study was constructed as a counterbalanced repeated measures design where each subject performed as his or her own control across the conditions. Prior to testing, each participant was given time and instruction to become familiar with the task. After verbalizing understanding of the task, each participant was performed the experimental protocol consisting of the following conditions: (a) right original learning to assess distal transfer learning from right-to-left direction, or (b) left original learning to assess distal transfer learning from left-to-right direction. Participants completed both conditions and thus used both hands for practice learning, original learning, and transfer learning. In between conditions, the participants were allowed rest time as requested.

Data Reduction and Analysis

The independent variables in the present study were the two different conditions as mentioned above. The dependent variables were: (a) the displacement of the pen in degrees, (b) the movement time or duration of the task, and (c) the muscular activity. Displacement of the pen was directly recorded by the measuring instrument and was converted into degrees by software that was calibrated before each experimental session. The duration of movement time was calculated by measuring the time between initiation and termination points of the movement and was measured from the velocity curve of the movements. Velocity curves of the movements were obtained by digitally differentiating the displacements or position curve of the movement over time. Initiation and termination points of a movement were taken as points where the velocity reached 5% of the peak velocity. The peak velocity was determined as the maximum velocity within a single movement. Measure of significant differences in motor condition parameters between original learning and transfer learning were assessed through the use of paired t-tests. A paired t-test is appropriate for this type of design with two observations on the repeated factor (Dawson-Saunders and Trapp, 1994, p. 107). One way ANOVA was applied when comparing means between OL, PL, and TL. A level of significance was adopted when p was found less than 0.05.

Results

Kinematic Profile

A graphical representation of the average kinematic profile and the associated electromyography recording from a representative subject are presented in Figure 2. In the representative example, the participant practiced the skill with left hand. Therefore, the original learning (OL) was assessed in the left hand and the transfer learning (TL) was assessed in the right hand. In this case, the transfer learning direction is left-to-right. It is readily evident that angular plots of average movements of the pen during practice, original, and transfer learning follow a similar profile (top panel) and this is further evident in the velocity profile as well (middle panel). It is relevant to mention that during both the original learning and transfer learning situations, the participants had to recall the task from memory and there was no feedback, in terms of knowledge of results, at the end of the task as the participants were writing with an inkless pen. During the practice learning, participants had to trace the letter, thus providing immediate and subsequent feedback of their performance. It is important to establish similarity in the kinematic profile between the practice, original, and transfer learning to ascertain that the learning of the task was accomplished. Similarity in the kinematic profile between practice learning, original learning, and transfer learning in Figure 2 established the fact that learning as well as transfer learning had taken place.

Further examination of the EMG profile revealed additional insight. The first dorsal interosseus muscle is functionally responsible for the abduction of the index finger (Norkin & Levangie, 1992). During several pilot studies in the laboratory, it was found that the first dorsal interosseus muscle was reliably active in certain phases of writing depending on the abduction force produced by the index finger against the pen. Since the writing styles and strategies differ among participants, the activity phase of the first dorsal interosseus muscle does not correlate among the participants, although in a single participant it is highly consistent with the kinematic profile of the pen movements for practice learning, original learning, and transfer learning. The bottom panel of Figure 2 represents the average EMG response from the first dorsal interosseus muscle during the learning task. The EMG for the average practice learning shows variability in timing of peaks, which is indicative of practice learning. The phasic bursts have not yet been controlled to form a smooth, practiced movement. The multiple peaks in this average EMG trace represent variable timing of EMG phasic bursts in different trials. As a result, during the averaging procedure in analysis, these peaks did not line up, indicating a lack of synchrony in regards to timing. As the learning proceeds, the synchronization begins to appear in the first phasic burst. That is, the formation of controlled muscle firing patterns begins to evolve. The original learning EMG average curve establishes temporal synchrony over repeated trials as the EMG phasic burst is mainly localized at two points: a small burst at the initial stage of performance and a large burst at the middle stage of performance. This further established the fact that learning is occurring. Characteristically, in the transfer learning performance, the initial and middle phasic bursts of EMG are fairly synchronized with the original learning EMG. This indicates a transfer of learning in terms of muscle programming. The muscle program that was established during the original learning is able to transfer to the opposite hand in the transfer learning sessions, as indicated by EMG phasic bursts.

Amplitude and Duration Parameters

The variables of importance were movement duration and movement amplitude during the OL and TL trials. Movement amplitude was measured as the vertical distance from the base line to the highest point of the amplitude curve. Table 1 shows the amplitude and duration parameters of right and left PL, OL, and TL. Spatial accuracy was judged by the superposition of average graphs of original learning and practice learning (Figure 2) as well as by testing for significant differences between the kinematic parameters associated with PL and OL. With an alpha level of 0.05, no significant differences were found in PL and OL in either amplitude and duration under any conditions. This signifies that the task was appropriately acquired through practice and was reproduced faithfully under recall. It is worth mentioning that subtle although non-significant differences were observed across data sets. In the right to left transfer, duration, but not the amplitude, was increased. This means the reproduction of the letter was accurate in terms of amplitude but the task was accomplished slowly. On the other hand, in the left to right transfer, duration, but not the amplitude, was decreased. This means the letter was once again accurate but the task was completed faster. This further signifies a transfer advantage from left to right in terms of temporal parameters. Furthermore, no significant differences were found in the percentage transfer advantage between right-to-left versus left-to-right, indicating that handedness played a minimal role in the transfer (Table 2).

Discussion

The present study examined the nature of intermanual transfer in the occupationally embedded motor learning task of writing a foreign alphabet. The results of the present study moderately support our main hypothesis. At the outset of the study we hypothesized that the transfer advantage would be asymmetric irrespective of the direction. This hypothesis was drawn from previous studies (Parlow & Kinsbourne, 1989; Thut, et al., 1996; Thut, et al., 1997). However, all of these previous studies employed tasks that were meaningless to the participants. For example, Thut, et al., (1996, 1997) employed a task that involved drawing eight meaningless figures. In light of recent findings that using occupationally embedded tasks produces better performance (Nelson, et al., 1996; Wu, et al., 1994; Wu, et al., 1998), we further hypothesized that our task would result in a better transfer advantage as it was assumed our chosen task is purposeful and meaningful to the participants. In the present study, we did not find any significant differences statistically either in temporal (e.g. movement time) or spatial (e.g., movement amplitude or accuracy) parameters between original learning and transfer learning irrespective of direction; that is, the transfer is equal from either left-to-right or right-to-left. This implies that almost a full transfer advantage was achieved by the participants and hand dominance did not result in a transfer advantage based on the use of right-hand dominant participants. We therefore conclude that in the present study the transfer was symmetric when the learning task is meaningful to the participants.

Task characteristics in transfer

We also hypothesized that there would be a transfer advantage in the temporal characteristics of the task from left to right; that is, from the non-dominant to the dominant side because of the known asymmetry of function between right and left hemispheres. This temporal characteristic is identified by a shorter duration (Thut, et al., 1996) meaning the task would be accomplished faster. Although we did not find a significant decrease in the duration of the task, the mean duration of task in the transfer learning hand is shorter than the task duration accomplished during original learning. Thus, it may be possible that there is a transfer advantage from the non-dominant side to the dominant side. Such non-dominant to dominant facilitation has been reported by previous researchers in normal participants (Thut, et al., 1996; Taylor & Heilman, 1980) as well as in split-brain patients (Thut, et al., 1997). Therefore, the present study confirms the earlier findings in this regard and supports the hypothesis that the task characteristics could be a determining factor in the transfer of learning.

We also hypothesized that there would be a transfer advantage in the spatial characteristics of the task in terms of amplitude and accuracy from the dominant to non-dominant side because of the known superiority of the right hemisphere in the spatial transposition of a task. However, we found an almost full transfer in terms of accuracy and amplitude in both directions. Therefore, the result of the present study is inconclusive in supporting the theorized asymmetry. The observed symmetry in terms of accuracy could be caused by two reasons. First is the complexity of the task and the second is the nature of the task. Recent studies on intermanual transfer of motor learning employing tasks that require higher levels of problem solving strategies (Lassonde, et al., 1986, Levin, et al., 1993) and tasks such as complex inverse mirror writing (Latash, 2000) concluded that intermanual transfer is task specific and depends on the level of motor processing and task characteristics. This implies that transfer degrades as the complexity of the task increases. The task chosen in the present study is simple to learn and is meaningful and purposeful to the participants. Therefore, the present task does not require a complex level of motor processing. These two factors might contribute to the symmetric transfer.

Proximal task versus distal task

It is generally argued that intermanual transfer of motor learning requires the presence of the corpus callosum connection (Lassonde, et al., 1986, Levin, et al., 1993). Anatomically, it has been found that a proximal to distal gradient exists in the interhemispheric callosal connection in the motor area of monkeys (Gould, et al., 1986; Pandya & Vignolo, 1971;). Therefore, it is likely that a novel learning task that requires the involvement of proximal muscle groups would have a better transfer advantage over a task that requires distal muscle groups. In fact, Thut, et al., (1996) found this predictive result when they compared a task of drawing meaningless figures involving either proximal or distal muscle groups. However, in a follow up study involving split-brain patients, Thut, et al., (1997) found a transfer advantage in the proximal task that was comparable to the normal subjects and a better transfer advantage in the distal task. They concluded that proximal or distal transfer of motor learning is possible through ipsilateral or below callosal level connections. Additionally, proximal interconnectivity via callosal fibers may exert inhibitory influences on the distal motor areas and therefore, a better transfer advantage was observed in the distal motor task in the absence of corpus callosal fibers. Although the results of the present study can neither prove nor disprove these assumptions, they present some interesting issues. First of all, the task of the present study can be regarded as a distal motor task and in spite of the presence of intact callosal connections we observed an almost full transfer advantage bi-directionally. Therefore, the results of the present study do not support the hypothesis of proximal callosal inhibition in a distal motor task. Rather, it appears that the transfer depends on the complexity of the distal task and task characteristics. Recently, Imamizu & Shimojo (1995) using a visuo-motor aiming task, concluded that the locus of intermanual transfer of learning is at the task level and depends on the task characteristics. Our results also support this hypothesis.

Implication in practice

Results of the present study hold promise in occupational therapy practice. It suggests that the training effect given to one side of the body can transfer to the other side of the body either to compensate for a lost motor function or to retrain a specific motor function. In a recent study on interhemispheric transfer of learning employing a relief maze task in unilateral brain damaged patients (Petrovici, et al., 1997) it was observed that the healthy hemisphere can compensate for some of the impaired higher cerebral functions through information transfer to the damaged hemisphere. In light of this observation and the results of the present study, we propose the following therapeutic principles in the case of intermanual motor learning transfer: (a) use of a simple task elicits better transfer than a complicated task, (b) use of an occupationally embedded task elicits a better transfer than use of a meaningless task, and (c) when selecting a task to transfer, it is important to pay attention to the temporal and spatial properties of the task since the transfer of learning appears to depend on the task characteristics.

Conclusion

The present study examines the intermanual transfer of motor learning employing a novel distal motor writing task in right-handed young participants. A symmetric transfer advantage was observed that did not depend on handedness. It appears that task characteristics and task simplicity play a role in the transfer of learning. It has been argued that such transfer may take place through corpus callosum connections. Results of the present study have important implications in occupational therapy practice especially in the case of relearning a new task or in compensating for a task in patients with disability. Further research on different varieties of tasks involving normal and patient populations are warranted as well as using meaningful and meaningless tasks.

Manuscript References

Brown, S. H., & Cooke, J. D. (1986). Initial agonist burst is modified by perturbations preceding movement. *Brain Research, 377*, 311-22.

Burgess, M. K. (1989). Motor control and the role of occupational therapy: Past, present, and future. *The American Journal of Occupational Therapy, 43*, 345-348.

Carr, J. H., & Shepherd, R. B. (1989). A motor learning model for stroke rehabilitation. Physiotherapy, 75, 372-380.

Crutchfield, C. A., & Barnes, M. R. (1993). *Motor control and motor learning in rehabilitation.* Atlanta: Stokesville.

Dawson-Saunders, B., & Trapp, R. G. (1994). *Basic and clinical biostatistics. 2nd Ed.* Norwalk, CT: Appleton & Lange.

Edwards, J. M., & Elliot, D. (1989). Asymmetries in intermanual transfer of training and motor overflow in adults with Down's syndrome and nonhandicapped children. *Journal of Clinical and Experimental Neuropsychology, 11*, 959-966.

Ferguson, J. M., & Trombly, C. A. (1997). The effect of added-purpose and meaningful occupation on motor learning. *The American Journal of Occupational Therapy, 51*, 508-515.

Gazzaniga, M. S. (1998). The split brain revisited. *Scientific American, 279*, 50-55.

Glickstein, J., & Hudak, M. T. (1999). Pathophysiology of stroke: A motor learning approach to treatment. *Focus on Geriatric Care and Rehabilitation, 13*, 1,3-11.

Gould, H. J., Cusick, C. G., Pons, T. P., & Kaas, J. H. (1986). The relationship of corpus callosum connections to electrical stimulation maps of motor, supplementary motor, and the frontal eye fields in owl monkeys. *Journal of Comprehensive Neurology, 247*, 297-325.

Hall, B. A., & Nelson, D. L. (1998). The effect of materials on performance: A kinematic analysis of eating. *The Scandinavian Journal of Occupational Therapy, 5*, 69-81.

Halsband, U. (1992). Left hemisphere preponderance in trajectorial learning. *Neuro Report, 3*, 397-400.

Hanlon, R. E. (1996). Motor learning following unilateral stroke. *Archives of Physical Medicine and Rehabilitation, 77*, 811-815.

Hicks, R. E. (1974). Asymmetry of bilateral transfer. *American Journal of Psychology, 87*, 667-674.

Hore, J., Ritchie, R., & Watts, S. (1999). Finger opening in an overarm throw is not triggered by proprioceptive feedback from elbow extension or wrist flexion. *Experimental Brain Research, 125*, 302-12.

Hore, J., Watts, S., Tweed, D., & Miller, B. (1996). Overarm throws with the non-dominant arm: kinematics of accuracy. *Journal of Neurophysiology, 76*, 3693-704.

Hoptman, M. J., & Davidson, R. J. (1994). How and why do the two cerebral hemispheres interact? *Psychological Bulletin, 116*, 195-219.

Imamizu, H., & Shimojo, S. (1995). The locus of visual-motor learning at the task or manipulator level: Implications from intermanual transfer. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 719-733.

Jarus, T. (1994). Motor learning and occupational therapy: The organization of practice. *The American Journal of Occupational Therapy, 48*, 810-816.

Lassonde, M., Sauerwein, H., Geoffroy, G., & Decarie, M. (1986). Effects of early and late transection of the corpus callosum in children: A study of tactile and tactuomotor transfer and integration. *Brain, 109*, 953-67.

Laszlo, J. I., Baguley, R. A., & Bairstow, P. J. (1970). Bilateral transfer in tapping skill in the absence of peripheral information. *Journal of Motor Behavior, 2*, 261-271.

Levin, H. S., Mattson, A. J., Levander, M., Lindquist, C. E., Simard, J. M., Guinto, F. C., Lilly, M. A., & Eisenberg, H. M. (1993). Effects of transcallosal surgery on interhemispheric transfer of information. *Surgical Neurology, 40*, 65-74.

Mathiowetz, V., & Wade, M. G. (1995). Task constraints and functional motor performance of individuals with and without multiple sclerosis. *Ecological Psychology, 7*, 99-123.

Nelson, D. L., Konosky, K., Fleharty, K., Webb, R., Newer, K., Hazboun, V. P., Fontane, C., & Licht, B. (1996). The effects of an occupationally embedded exercise on bilaterally assisted supination in persons with hemiplegia. *The American Journal of Occupational Therapy, 50*, 639-646.

Norkin, C., & Levangie, P. (1992). *Joint structure and function: A comprehensive analysis. 2nd Ed.* Philadelphia: F. A. Davis Company.

Pandya, D. N., & Vignolo, L. A. (1971). Intra- and interhemispheric projections of the precentral, premotor, and arcuate areas in the rhesus monkey. *Brain Research, 26*, 217-33.

Parlow, S. E., & Kinsbourne, M. (1989). Asymmetrical transfer of training between hands: Implications for interhemispheric communication in normal brain. *Brain Cognition, 11*, 98-113.

Parlow, S. E., & Kinsbourne, M. (1990). Asymmetrical transfer of braille acquisition between hands. *Brain and Language, 39*, 319-330.

Parlow, S. E., & Dewey, D. (1991). The temporal locus of training between hands: An interference study. *Behavior Brain Research, 46*, 1-8.

Petrovici, J. N. (1997). Interhemispheric transfer of learning in brain-damaged patients. *Journal of Neurosurgical Sciences, 41*, 97-105.

Poole, J. L. (1991). Application of motor learning principles in occupational therapy. *The American Journal of Occupational Therapy, 45*, 531-537.

Ross, L., & Nelson, D. (2000). Comparing materials-based occupation, imagery-based occupation, and rote movement through kinematic analysis of reach. *The Occupational Therapy Journal of Research, 20*, 45-60.

Sabari, J. S. (1991). Motor learning concepts applied to activity-based intervention with adults with hemiplegia. *The American Journal of Occupational Therapy, 45*, 523-530.

Shiratori, T, & Latash, M. (2000). The roles of proximal and distal muscles in anticipatory postural adjustments under asymmetrical perturbations and during standing on rollerskates. *Clinical Neurophysiology, 111*, 613-23.

Sperry, R. W. (1974). Lateral specialization in the surgically separated hemispheres. In *The Neuroscience: Third Study Program*, F.O. Schmitt and F.G. Worden (eds). Cambridge, MA: The MIT press, pp. 5-19.

Sperry, R.W. (1982). Some effects of disconnecting the cerebral hemispheres. *Science 217*, 1223-1226.

Stoddard, J., & Vaid, J. (1996). Asymmetries in intermanual transfer of maze learning in right- and left-handed adults. *Neuropsychologia, 34*, 605-608.

Taylor, H. G., & Heilman, K. M. (1980). Left hemisphere motor dominance in righthanders. *Cortex, 16*, 587-603.

Thut, G., Cook, N. D., Regard, M., Leenders, K. L., Halsband, U., & Landis, T. (1996). Intermanual transfer of proximal and distal motor engrams in humans. *Experimental Brain Research, 108*, 321-327.

Thut, G., Halsband, U., Regard, M., Mayer, E., Leenders, K. L., & Landis, T. (1997a). What is the role of the corpus callosum in intermanual transfer of motor skills? A study of three cases with callosal pathology. *Experimental Brain Research, 113*, 365-370.

Thut, G., Roelcke, U., Nienhusmeier, M., Missimer, J., Maguire, R. P., Regard, M., Landis, T., & Leenders, K. L. (1997b). Intermanual transfer for training: Blood flow correlates in the human brain. *Behavioral Brain Research, 89*, 129-134.

Thut, G., Hauert, C. A., Morand, S., Seeck, M., Landis, T., & Michel, C. (1999). Evidence of interhemispheric motor-level transfer in a simple reaction time task: An EEG study. *Experimental Brain Research, 128*, 256-261.

Trombly, C. A., & Wu, C. Y. (1999). Effect of rehabilitation tasks on organization of movement after stroke. *The American Journal of Occupational Therapy, 53*, 333-343.

Wu, C., Trombly, C., & Lin, K. (1994). The relationship between occupational form and occupational performance: A kinematic perspective. *The American Journal of Occupational Therapy, 48*, 679-687.

Wu, C., Trombly, C. A., Lin, K., & Tickle-Degnen, L. (1998). Effects of object affordances on reaching performances in persons with and without cerebrovascular accident. *The American Journal of Occupational Therapy, 52*, 447-56.

Tables

Table 1

Amplitude and Duration Parameters for Right to Left and Left to Right Conditions (n=10)

variable and condition	Right to Left		Left to Right	
Amplitude (degrees)	M	SD	M	SD
Practice Learning	17.15	2.25	20.68	4.52
Original Learning	19.43	3.86	22.27	7.61
Transfer Learning	20.21	4.44	20.31	3.77
Duration (seconds)				
Practice Learning	2.147	0.65	2.357	0.62
Original Learning	1.979	0.63	2.130	0.58
Transfer Learning	2.350	0.70	2.000	0.51

Note. Practice Learning values taken from 10 subjects over 60 trials. Original Learning and Transfer Learning values taken from 10 subjects over 100 trials. No significant differences found in motor parameters between OL and TL when assessed by paired t-test or between PL, OL, and, TL when assessed by one-way ANOVA.

Table 2

Percentage Transfer for Spatial Properties (Amplitude) and Temporal Properties (Duration) across Conditions

variable and direction of transfer	M	SD
Duration		
Right to Left	125.09	30.26
Left to Right	90.47	6.97
Amplitude		
Right to Left	120.35	28.05
Left to Right	98.78	30.27

Note. Transfer percentage was calculated in relation to original learning parameters.

Figure Captions

Figure 1. The subject pictured is wearing a wrist brace and the non-writing hand is placed on the forearm of the writing arm to prevent any extraneous wrist movements. The sensor coil is attached to the top of the pen and forms a composite of the writing movements. The electromyography sensor is attached on the skin overlying the muscle belly of the first dorsal interosseus of the writing hand.

Figure 2. Depicted in the figure are the graphical representations of the kinematic movements and electromyography recordings from a representative subject. The subject performed practice learning and original learning sessions with the left hand. Transfer learning was assessed in the right hand. Note the similarity in the kinematic profile between practice learning, original learning, and transfer learning. This indicates that learning and transfer of learning has occurred. The electromyography profiles of practice learning and original learning depict muscle training has occurred. In the transfer learning profile, the phasic bursts are fairly synchronized with the original learning suggesting muscle programming transfer.

Figures

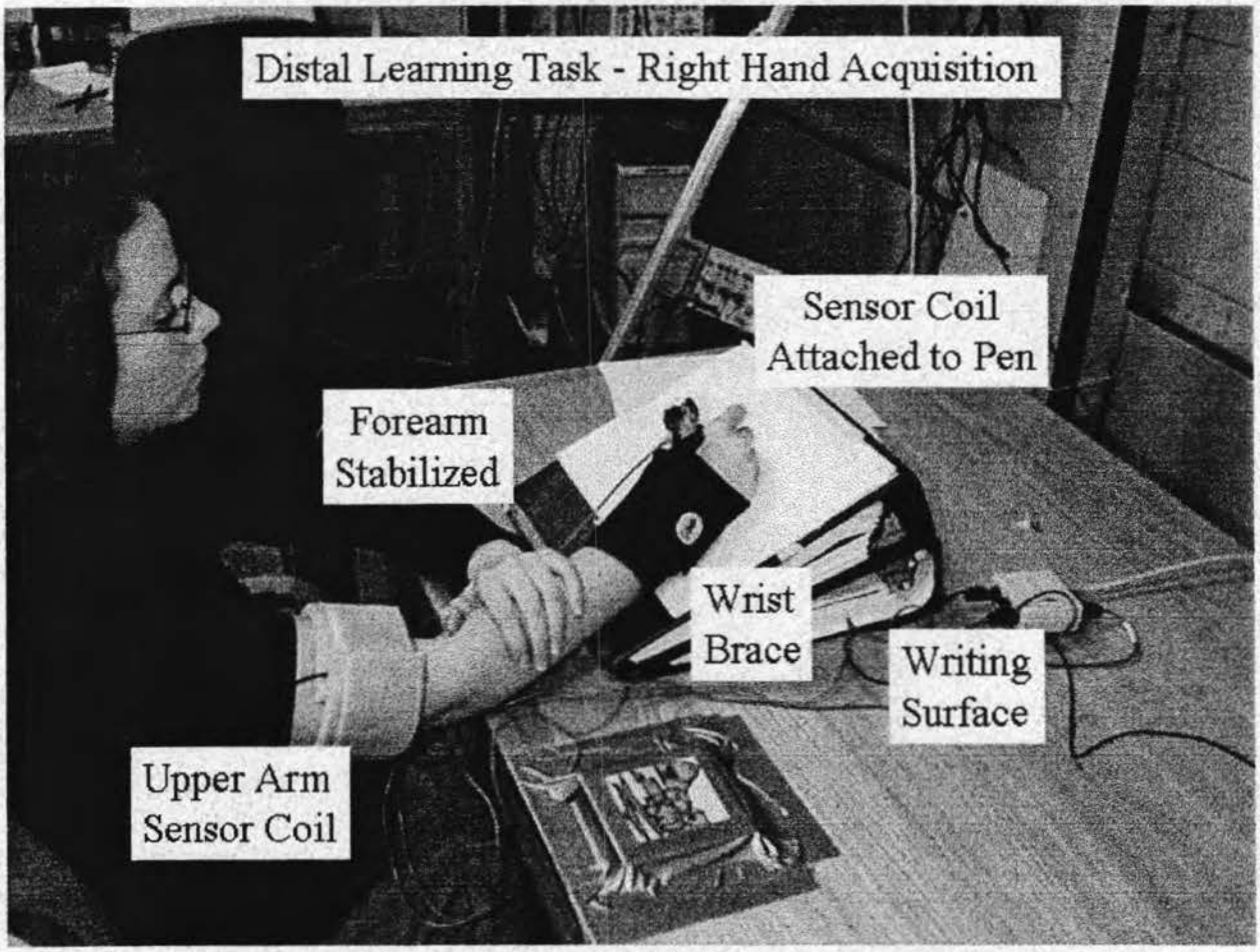

Figure 1. Representative Subject Engaged in Learning Task

Distal Acquisition - Left Hand

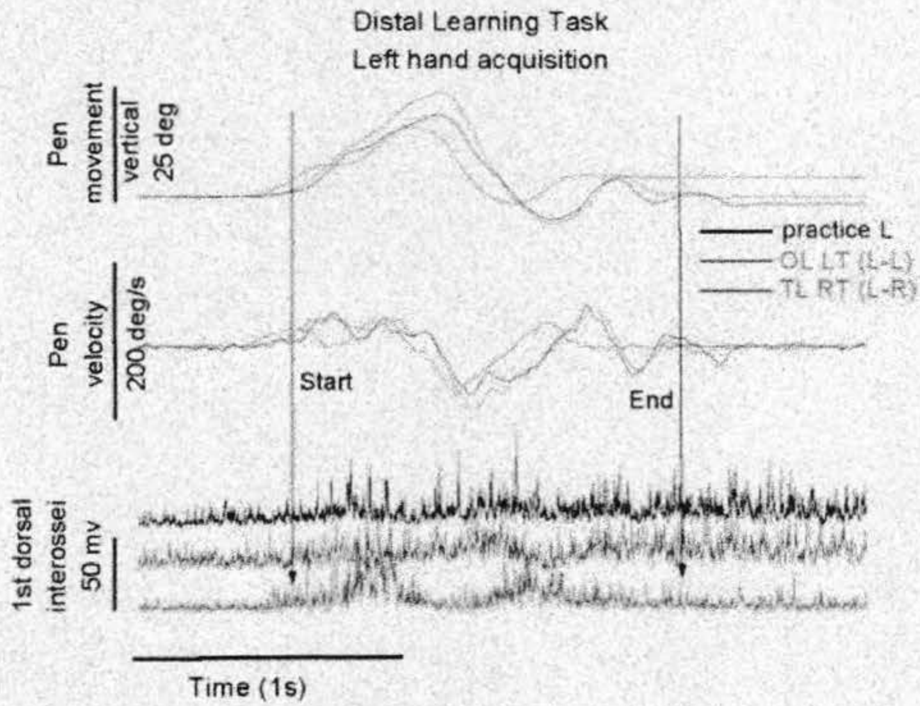

Figure 2.

Appendix - Human Subjects Materials

All College Review Board for Human Subjects Research

Investigators: Megan Andree, BS, Kinsuk K. Maitra, Ph.D.

Department: Occupational Therapy

Date Submitted: November 19, 1999

Telephone: W: 4-1736, H: 256-8425

Title of Project: Intermanual transfer of a novel writing task in young adults

Abstract: All movements that we make in our lifetime are learned either during natural maturation of thereafter through practice. The process by which we acquire and retain a skill to accomplish a particular task is called motor learning. Humans show lateral preferences in unilateral motor skills. One good example is writing the alphabet. Although we learn to write the alphabet with our dominant hand, we can also write the same alphabet with our non-dominant hand, though not of comparable quality. Therefore, some transfer of learning occurs to the other hand during the process of motor learning. The nature or amount of such transfer is not known. Therapeutically, the issue is important. In treating patients, for example with hand/arm amputation, stroke, or hemiparkinsonism, therapists can take advantage of such learning transfer in the unaffected side. The purpose of the present study is to explore the nature of intermanual transfer of a novel motor task in right handed, young adult individuals without disabilities. The novel task in this study will be a non-Latin alphabet. Subjects will practice the alphabet with their right or left hand. Performance of practiced and non-practiced hands will be recorded by recording the movements of the pen using a movement recording system based on 'search coil.' The time series data will be stored for off-line analysis. Movement variables, like amplitude of pen movement, velocity, and acceleration will be examined and compared between practiced and non-practiced hands to assess intermanual transfer of motor learning.

Proposed Date of Implementation: December, 1999

Name: Megan Andree	**Name:** Kinsuk K. Maitra
Signature:	**Signature:**
(Use blue ink)	(Use blue ink)
Principal Investigator	**Faculty Advisor**

ALL-COLLEGE REVIEW BOARD
FOR
HUMAN SUBJECTS RESEARCH

CHECKLIST

Project Title: Intermanual Transfer of a Novel Writing Task in Young Adults

Investigator(s): Megan Andree and Professor Kinsuk Maitra

Investigator Use	HSR Use Only	Items for Checklist
/		1. General information
/		2. Related experience of investigator(s)
/		3. Benefits of the study
/		4. Description of subjects
/		5. Description of subject participation
/		6. Description of ethical issues/risks to participation
/		7. Description of recruitment of subjects
/		8. Description of how anonymity/confidentiality will be maintained
NA		9. Debriefing statement
NA		10. Compensatory follow-up
/		11. Appendix A- Recruitment Statement
/		12. Appendix B - Informed Consent Form (or tear-off Cover Page for anonymous paper and pen/pencil surveys)
NA		13. Appendix C - Debriefing Statement
NA		14. Appendix D - Survey Instruments
NA		15. Appendix E - Glossary to questionnaires

Items 1-8, 11, and 12 must be addressed and included in the proposal. Items 9, 10, and 13-15 should also be checked if they are appropriate - indicate "NA" if not appropriate. This should be the second page of the proposal.

Intermanual transfer of a novel writing task in young adults

1. General information about the study.

a) Funding. No funding is available at this time although the department is discussing options to provide some dollar amount to cover basic supply and stationery costs. In the event of unavailability of such funding, the student (Megan Andree) will cover these basic costs. Laboratory space and necessary equipment are already in place; they have come from a seed-grant to Dr. Kinsuk Maitra (Faculty Advisor).

b) Location. The study will take place at Ithaca College in the occupational therapy research laboratory (Center for Health Sciences (CHS) building, room 213).

c) Time Period. Subjects will be recruited and tested from December 1999 to March 2000.

d) Definition of Terms

Motor learning: the process of acquiring skills to perform a movement and retaining those skills for future use in the same movement.

Intermanual transfer: the transfer of motor learning from one limb to another.

2. Related Experience of the Researcher.

Megan Andree is an occupational therapy graduate student knowledgeable of the research methods of occupational therapy. Presently, she is tasking a course in Research Methods (672-67000) to further broaden her knowledge in this area. An individual thesis is part of the requirements to fulfill the masters degree in occupational therapy. Previous courses in the occupational therapy curriculum have provided her with a knowledge base on the area of her research interest; that is, motor learning. These courses include Physics, Neuroscience, Kinesiology, and Adult Neuroscience. Megan is presently working with Dr. Maitra in preparing her research proposal. She is also learning to use the instrumentation in the laboratory.

Kinsuk K. Maitra is an Assistant Professor, who has been at Ithaca College for five years. He has extensive previous research experience in movement studies. He has completed seven projects with human subjects over the last ten years. In one project the aforementioned technology was used.

3. Benefits of the Study.

The study will look at the intermanual transfer of motor learning from one hand to the other hand. Such studies have important clinical implications in rehabilitation of patients with motor dysfunctions such as stroke (hemiplegia), hemi-parkinsonism, etc. Furthermore, the outcome of the study is expected to add to the knowledge bases of various fields including occupational therapy, physical therapy, motor learning, and neuroscience.

4. Description of Subjects.

a) Number of Subjects. 10 subjects will be included in the study.

b) Salient characteristics. The subject population will consist of the right-handed male and / or female college students without disability who are naïve to the design of the study.

5. Description of Subject Participation.

The subjects will be introduced to a non-Latin alphabet (Bengali) and asked to practice copying that alphabet for one hour with their assigned hand in the laboratory.

They will be told that they must practice only with their assigned hand. They will be asked to reproduce the alphabet with their practiced as well as with their non-practiced hand. The movement of the pen while writing with their practiced hand and non-practiced hand will be recorded by attaching a light-weight movement sensor (2 cm. diameter) to the pen. A number of ten writings will be recorded in a single session by either hand. Our movement recording system is an advanced version of the angle detector described in detail by Koch (1980) and is now commercially available (Dr. Lutz Neumann, Germany). Similar systems have been used to record human limb movements (1,2), eye and eyelid movements (3), and wing movement of insects (4).

6. Ethical Issues.

a) Risks of Participation. No physical or emotional risks either to the subjects or to the experimenter are involved or anticipated in the study.

b) Informed Consent. Please see attached form in Appendix A2.

7. Recruitment of Subjects.

a) Recruitment Procedures. Only right-handed subjects will be recruited on a voluntary basis from the Ithaca College student community. Recruitment flyers (see Appendix A1) will be posted throughout the college campus. All potential subjects will attend an orientation session in which the research protocol will be described and the project's risks and benefits will be thoroughly explained. The subjects will be assured that participation in the study is strictly voluntary and they can withdraw from the study at anytime without penalty. They will be further assured that their identity will not be associated with the results of the study or any communication related to the study.

b) Inducement to Participate. There will be no inducement for subjects' participation in the study.

8. Confidentiality / Anonymity of Responses.

The only identifying information to be collected from subjects is their gender and age. A code number will be given to identify each subject for references and this information will be kept confidential in the advisor's office. In the thesis or any other form of publication the subjects' names will not be mentioned.

9. Debriefing.

Since there is no deception in the study, no formal debriefing session is required.

10. Compensatory Follow-Up (If Appropriate).

There will not be a need for compensatory follow-up following the subjects' participation in the study.

References

1. Hore, J., Watts, S., Vilis, T. (1992). Constraints on arm position when pointing in three dimensions: Donder's law and the Fink gimbal strategy. Journal of Neurophysiology, 68, 374-383.

2. Hore, J., Watts, S., Tweed, D. (1994). Arm positions constraints when throwing in three dimensions. Journal of Neurophysiology, 72: 1171-1180.

3. Abell, K. M., Cowen, D. E., Baker, R. S., Porter, J. D. (1999). Eyelid kinematics following blepharoplasty. Ophthalmic Plastic Reconstructive Surgery, 15 (4): 236-242.

4. Koch, U. T. (1980). Analysis of cricket stridulation using miniature angle detectors. Journal of Comparative Physiology, 136: 247-256.

Human Subjects Appendix A1 - Subject Recruitment Flyer

Right-handed volunteers (age between 20-30 years) wanted to participate in an occupational therapy research study on motor learning

What you do: You come to the laboratory and practice learning a foreign alphabet

What we do: After practicing, we will record the movement of the pen with a motion sensor while you are writing the alphabet

What you get: An appreciation of graduate research. Learn more about motor learning.

We need: 2 hours commitment of time.

Please contact:
Megan Andree
phone: 256-8425
e-mail: mandree1@ic3.ithaca.edu

Human Subjects Appendix A2 - Informed Consent Form

INFORMED CONSENT FORM

Intermanual Transfer of a Novel Writing Task in Young Adults

1. Purpose of the Study. The primary purpose of the study will be to assess the degree of motor learning achieved in performing a novel task.

2. Benefits of the Study. The benefits of the study will be the addition of information to the knowledge bases of occupational therapy, neuroscience and motor learning.

3. What You Will Be Asked to Do. You will be asked to participate in an experiment. The actual experiment time will be approximately 1-2 hours. You will be given two sample foreign alphabet letters and be asked to practice copying each alphabet 6 times. After you have practiced, you will be asked to write the alphabet 10 times. A small motion sensor will be attached to the pen and another sensor will be attached to your upper arm. Non-invasive electromyography (EMG) sensors will be attached to the hand that is writing to record muscle activity. You will be asked to wear a wrist brace while writing. The movements of the pen and your arm will be recorded along with the muscle activity in your hand during the task of writing. You will be asked to write the same alphabet for a total of 64 times and 64 pen movements will be recorded.

4. Risks. There is no emotional or physical risk involved in the study.

5. If You Would Like More Information about the Study.

   For any information before, during, or after the study please feel free to contact:

   Megan Andree
   E-mail: mandree1@ic3.ithaca.edu
   Phone: 607-256-8425

6. Withdrawal from the Study. You are free to withdraw from the study at any time.

7. How the Data will be Maintained in Confidence. All of the data from this study are confidential. This means that your name will not be used in any way and your performance will never be identified as coming from you.

I have read the above and understand its contents. I agree to participate in the study. I acknowledge that I am 18 years of age or older.

________________________ ______________________________

Print or Type Name   Signature and Date